PERMO-CARBONIFEROUS STRATIGRAPHY OF THE BANFF-JASPER AREA, ALBERTA

H. R. RUDY

1958

PLATE I

Panorama of Mount White, on north end of Bare Mountains, Latitude 51°40', Longitude 115°49'. View looking south-west from valley of Red Deer River, showing typical Carboniferous section.

THE UNIVERSITY OF ALBERTA

PERMO-CARBONIFEROUS STRATIGRAPHY OF THE BANFF-JASPER AREA, ALBERTA

A DISSERTATION
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

FACULTY OF GRADUATE STUDIES

DEPARTMENT OF GEOLOGY

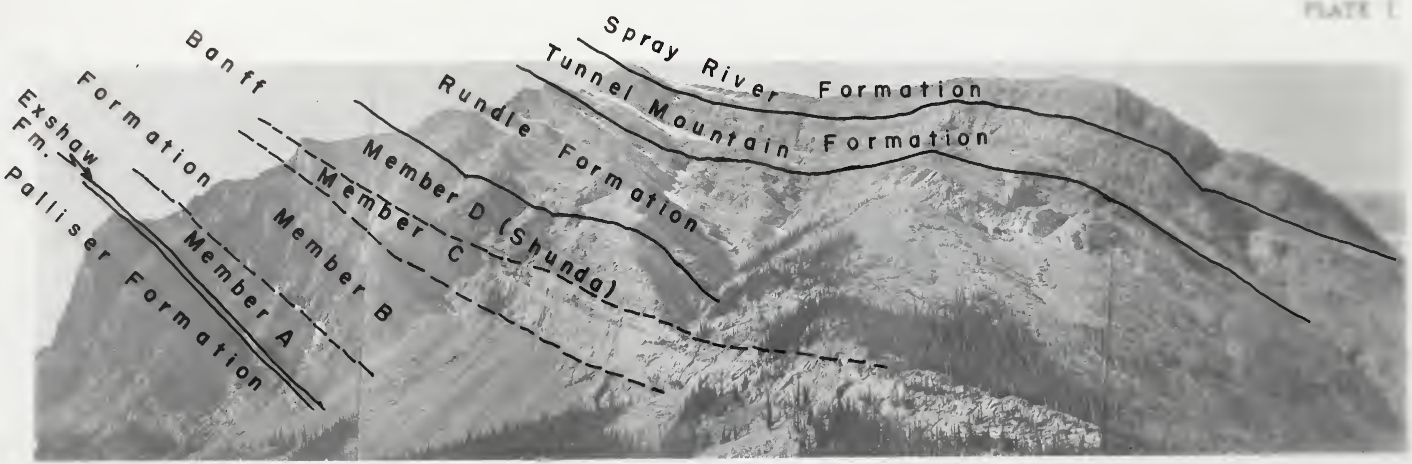
by

HAROLD ROY RUDY

EDMONTON, ALBERTA

APRIL, 1958

PLATE 1



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ABSTRACT

Permo-Carboniferous strata of the Rocky Mountain Front Ranges between Banff and Jasper, Alberta, are described and correlated to the Mount Greenock section at Jasper and the type sections at Banff. Four conformable formations are recognized. In ascending order, these are the: Exshaw, Banff, Rundle and Tunnel Mountain. The history and development of Permo-Carboniferous nomenclature of the Canadian Rockies is summarized.

The Upper Devonian or Lower Mississippian Exshaw formation consists of approximately 35 feet of black shale. The Banff formation, an argillaceous unit ranging from 900 to 1500 feet in thickness, contains four easily-recognizable members. Member A, composed of calcareous shales, is equivalent to type Lower Banff; Member B of interbedded limestones and shales is equivalent to type Middle Banff; Member C, a crinoidal limestone unit, is not present in type Banff and may be equivalent to the Pekisko formation of southern Alberta; and Member D consists of argillaceous limestones equivalent to both type Shunda and to most of type Upper Banff. Members A and B are considered to be Kinderhookian, and C and D Osagean in age. The Rundle formation consists of from 800 to 2200 feet of carbonates. Two members are recognized; a Lower member of light-coloured crinoidal limestones equivalent to the Osagean Livingstone formation, and an Upper member of dark-coloured limestones equivalent to the

Meramecian Mount Head formation. The Tunnel Mountain formation, the uppermost unit, consists of from 200 to 600 feet of silty dolomites ranging from Chesterian to Pennsylvanian in age.

Significant conclusions resulting from this study are that type Shunda is equivalent to most of type Upper Banff; and that the Tunnel Mountain formation is a facies of the Rundle, becoming older north of Banff.

ACKNOWLEDGEMENTS

The writer is indebted to Drs. O.A. Erdman and A.D. Baillie of The British American Oil Company Limited, for permission to use material and information obtained during the previous four field seasons. Mr. James Hamilton, of the same company, helped the writer considerably by providing information and samples and discussion of conflicting ideas.

Dr. S.J. Nelson of the Department of Geology, University of Alberta, as thesis supervisor, offered guidance and valuable criticism during the preparation of this thesis. Information and criticism received from Drs. P.S. Warren and C.R. Stelck, of the same department, are gratefully acknowledged.

Thanks are also due the Pan American Petroleum Corporation, who provided a fellowship enabling the writer to complete this thesis.

A vote of thanks is due the writer's wife, who greatly assisted by typing the manuscript.

TABLE OF CONTENTS

ILLUSTRATIONS

PLATES

FIGURES

TABLES

CHAPTER I

INTRODUCTION

General Statement

The purpose of this thesis is to describe the Permo-Carboniferous strata of the Rocky Mountain Front Ranges between Banff and Jasper, Alberta, and to correlate this strata with the Permo-Carboniferous type section (of Beales, 1951) at Banff and with the Greenock type section (of Brown, 1952) at Jasper. For convenience, this intervening area, between Banff and Jasper, will hereafter be referred to as the present area. The stratigraphic position of the type Shunda formation (Stearn, 1956), with respect to its use at Banff and Turner Valley, is clarified, supported by both lithologic and faunal evidence. An outline of the history of Carboniferous nomenclature within Western Alberta shows how stratigraphic taxonomy resulted in confusion in correlation.

Detailed descriptions of measured sections are not presented. Correlation by major rock units is used, as this method is found to be simpler and more comprehensive than using fine subdivisions of formations, except locally.

Reference is made to several manuscripts of papers by Raasch (1958), Harker and Raasch (1958) and Moore (1958a, 1958b) which will appear in the forthcoming Allan Memorial Volume of the American Association Of Petroleum Geologists. Subsequent changes in these manuscripts may arise, prior to publication.

Although the Rocky Mountain Front Ranges between Banff and Jasper, Alberta, have been studied in considerable detail by numerous oil companies, few of these studies have been published (Howard, 1954 thesis). Permo-Carboniferous sections at Banff and Jasper have been described by the Geological Survey of Canada, but little to no information is available concerning the intervening area.

In the summer of 1957, The British American Oil Company Limited sent a six-man stratigraphic party to study the Carboniferous in the area extending northward from Banff to the North Saskatchewan River. The writer was privileged to be a member of this party and from field notes and lithologic samples obtained was able to make this thesis study. Supplementary data obtained by The British American Oil Company Limited field parties in previous summers from the area between Jasper, Alberta and the North Saskatchewan River, have been made available to the writer. Detailed lithologic studies and faunal collections of Mississippian type sections both at Banff and Jasper were made in the fall of 1956 and 1957 by Dr. S. J. Nelson and the writer.

Area And Field Work

The area studied lies in the Rocky Mountain Front Ranges between 51° 00' and 53° 15' north latitude and between 115° 20' and 118° 20' west longitude (See Figure 1 , p. 5). Stratigraphic sections used in this report were measured in the main Front Ranges (See Figure 2 , p. 6). One section occurs in the outlying Brazeau

Range but no section west of the "third" range was studied. The northwesterly striking Rocky Mountains trend for 170 miles diagonally across this area with Banff being in the extreme south-east corner and Jasper in the northwest corner.

Because the area embraces both Banff and Jasper National Parks, accessibility is good. Park fire-roads and forest ranger roads permit the use of trucks and cars to a large extent. The best mode of travel within the parks is by pack-string which permits the use of numerous pack-trails. Access to the sections was by pack-horses, though a half-ton panel truck proved useful for obtaining supplies. Where possible, transportation to the sections by truck was used, though often horses were preferable.

Detailed stratigraphic work in the area was carried out during the summer field season of 1957 under the auspices of The British American Oil Company Limited, Calgary, Alberta. Personnel of the field party included Dr. S. J. Nelson, party chief, James Hamilton, Arthur Grunder, John Twyman, Donald Basso and the writer.

Sections were measured with a five-foot staff and Brunton compass.

Physiography and Structure

The Rocky Mountain Front Ranges trend northwest-southeast within the area and are bounded on the east by the foothills of Alberta. The former have an average elevation of 9,000 - 10,000

feet and are a series of parallel fault blocks or "ranges" usually dipping west-southwest. Generally, they provide excellent exposures of stratigraphic section.

The Front Ranges are crossed by several large easterly and northeasterly flowing rivers: principally the Bow, Red Deer, Clearwater, North Saskatchewan, Brazeau and Athabasca Rivers. Excellent exposures of Carboniferous and Devonian strata are generally found where these rivers and tributaries cut across the fault blocks or "ranges".

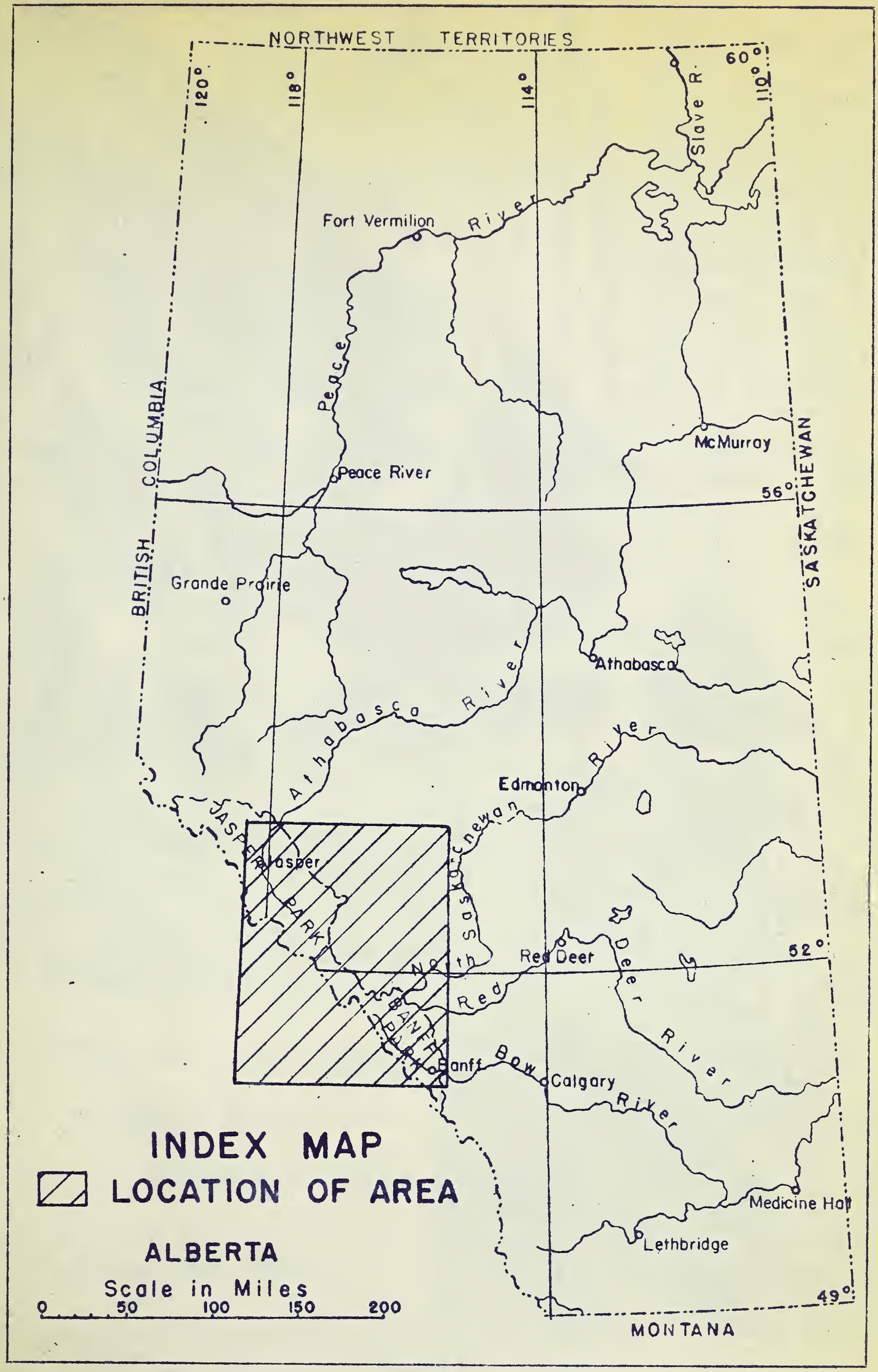

NORTHWEST TERRITORIES
120°
118°
114°
110°
60°
56°
52°
49°
Slave R.
Fort Vermilion
River
Peace
Peace River
McMurray
BRITISH COLUMBIA
SASKATCHEWAN
Grande Prairie
Athabasca River
Athabasca
Edmonton
North Saskatchewan River
JASPER PARK
Jasper
Red Deer
Red Deer River
BANFF PARK
Banff
Bow River
Calgary
Medicine Hat
Lethbridge
MONTANA
INDEX MAP
LOCATION OF AREA
ALBERTA
Scale in Miles
0 50 100 150 200

Figure 1

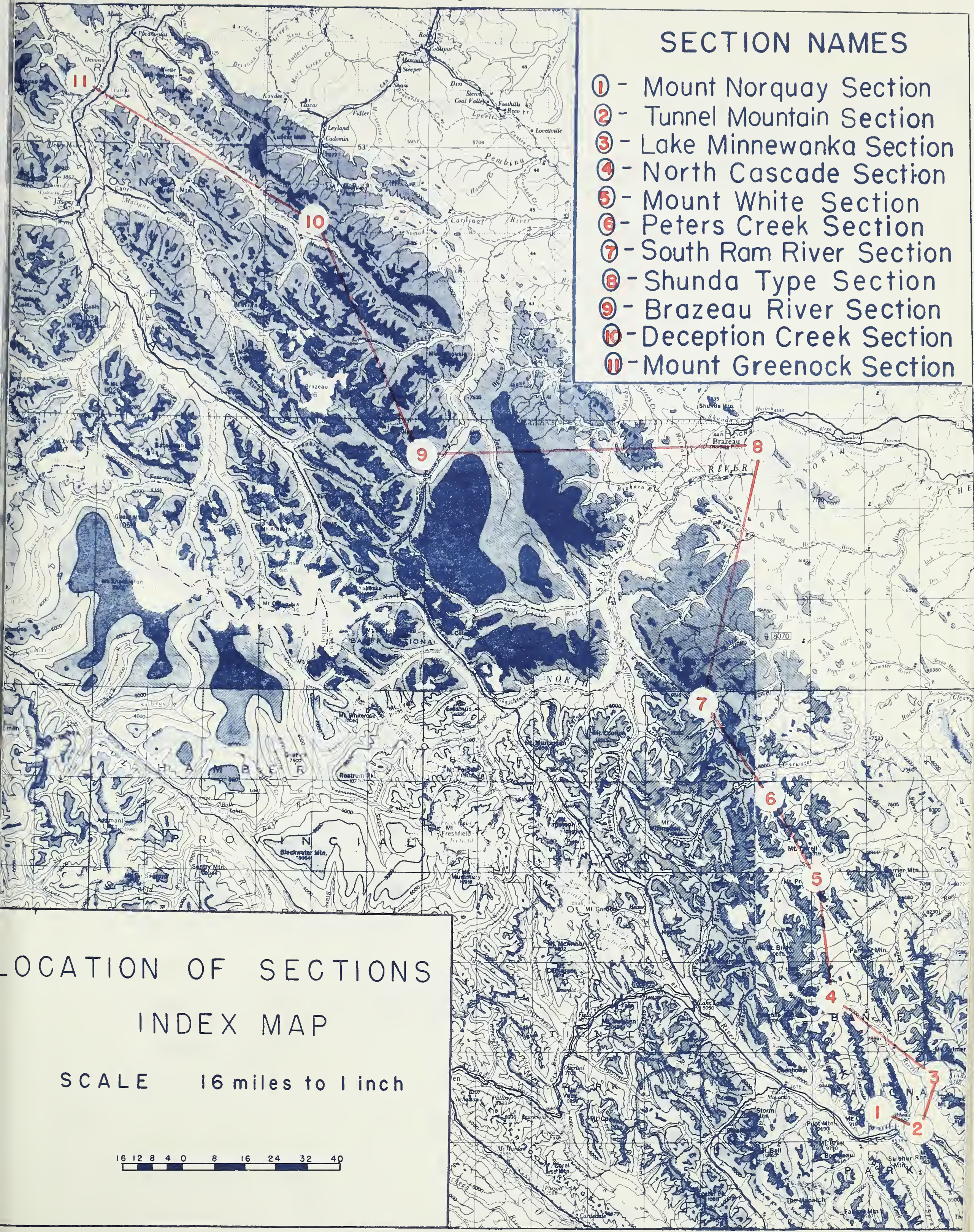

SECTION NAMES
1 - Mount Norquay Section
2 - Tunnel Mountain Section
3 - Lake Minnewanka Section
4 - North Cascade Section
5 - Mount White Section
6 - Peters Creek Section
7 - South Ram River Section
8 - Shunda Type Section
9 - Brazeau River Section
10 - Deception Creek Section
11 - Mount Greenock Section
LOCATION OF SECTIONS
INDEX MAP
SCALE 16 miles to 1 inch
16 12 8 4 0 8 16 24 32 40

Figure 2

CHAPTER II

HISTORY AND DEVELOPMENT OF PERMO-CARBONIFEROUS NOMENCLATURE

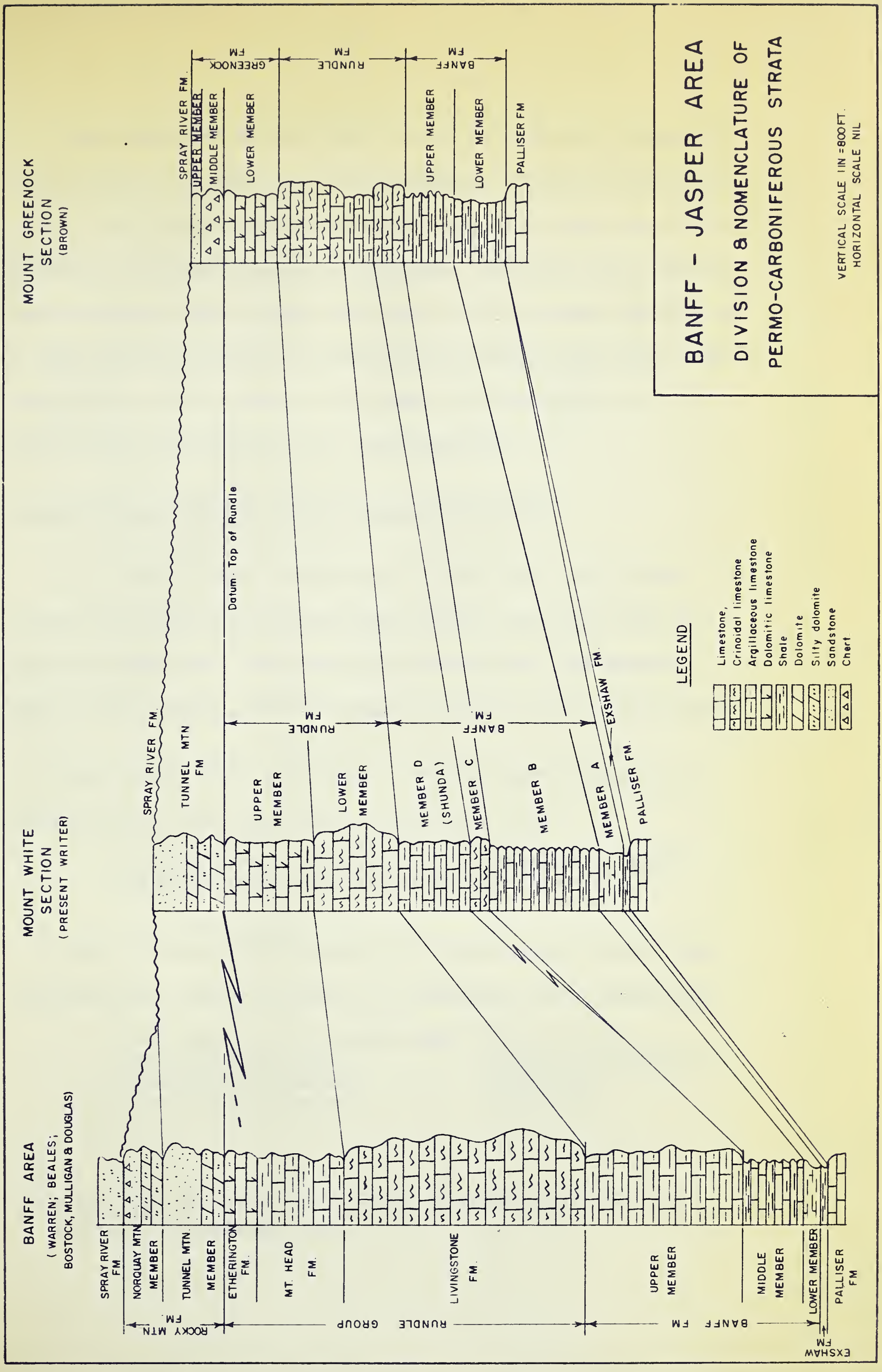
The Carboniferous system in Europe is divided into Upper and Lower, and in the United States into Pennsylvanian and Mississippian respectively, as a rough equivalent. The Upper Carboniferous of Western United States once included strata now placed in Permian. Following north on American correlation, Permian beds in Western Canada were assigned to the Pennsylvanian. The strata of this thesis fall into Permo-Carboniferous position. The idea that all *Lithostrotion* of North America were of Pennsylvanian age gave the name *Lithostrotion pennsylvanicum* to one of the Mississippian corals. Geologists working with this Upper Palaeozoic strata, introduced manuscript names, and different interpretations following oral presentation led to ambiguity. Thus, historical background, homotaxy and facies changes of Upper Palaeozoic strata of Western Canada all contributed to nomenclatural and correlative misinterpretations.

The Permo-Carboniferous of Western Canada is composed of three major lithologic units. These are, in ascending order: the Banff formation, a predominantly shaly facies; the Rundle formation, a limy facies; and the Rocky Mountain formation, a clastic, sandy to silty facies.

Of all the Palaeozoic strata in the Rocky Mountains and Foothills of Western Canada, the Permo-Carboniferous are some of the most difficult to interpret. As a result, considerable change and revision through the years has resulted in appalling confusion of the nomenclature. It is the purpose of this chapter to outline the history and revisions of this nomenclature. In order to familiarize the reader with Carboniferous terms, a composite table from the Banff and Mount Head areas is presented below:

Table of Formations

System	Stages	Formation		Member
Triassic		Spray River		
Permian ?		Rocky Mountain		Norquay Mountain
Pennsylvanian ?				Tunnel Mountain
Mississippian	Chesterian	Rundle Group	Etherington	
	Meramecian		Mount Head	(Carnarvon (Marston (Cummings (Salter (Baril (Wileman
	?			
	Osagean		Livingstone	(Turner Valley (Pekisko
	?			
	Kinderhookian	Banff		(Upper (Middle (Lower
Devonian		Exshaw		


BANFF - JASPER AREA
DIVISION & NOMENCLATURE OF
PERMO-CARBONIFEROUS STRATA
VERTICAL SCALE 1 IN = 800 FT.
HORIZONTAL SCALE NIL
BANFF AREA
(WARREN; BEALES;
BOSTOCK, MULLIGAN & DOUGLAS)
MOUNT WHITE
SECTION
(PRESENT WRITER)
MOUNT GREENOCK
SECTION
(BROWN)
SPRAY RIVER FM
NORQUAY MTN MEMBER
TUNNEL MTN. MEMBER
ROCKY MTN FM.
ETHERINGTON FM.
MT. HEAD FM.
LIVINGSTONE FM.
RUNDLE GROUP
UPPER MEMBER
MIDDLE MEMBER
LOWER MEMBER
BANFF FM
EXSHAW FM
PALLISER FM
SPRAY RIVER FM.
TUNNEL MTN FM
UPPER MEMBER
LOWER MEMBER
RUNDLE FM
MEMBER D (SHUNDA)
MEMBER C
MEMBER B
MEMBER A
BANFF FM.
EXSHAW FM.
PALLISER FM.
Datum: Top of Rundle
SPRAY RIVER FM.
UPPER MEMBER
MIDDLE MEMBER
LOWER MEMBER
GREENOCK FM
RUNDLE FM
UPPER MEMBER
LOWER MEMBER
BANFF FM
PALLISER FM
LEGEND
Limestone,
Crinoidal limestone
Argillaceous limestone
Dolomitic limestone
Shale
Dolomite
Silty dolomite
Sandstone
Chert

This chapter is in two parts: (a) a chronological history of nomenclature up to 1947, and (b) development of nomenclature after 1947. Up to 1947, changes were mainly regional, while units were formations of broad lithologic divisions. After that year, detailed local studies raised certain formations to group status and produced a finer subdivision of the formations into members (See Table 2, p.28). Presentation in this manner should make the development of Mississippian nomenclature more comprehensible.

A Chronological History Of Nomenclature Up To 1947

The first published information on the Cordilleran Carboniferous was given by Sir James Hector (1859), geologist with the Palliser expedition. He recognized Carboniferous limestones by their fossil content, but no attempt was made to name these strata.

G.M. Dawson (1886) described two stratigraphic divisions in the Bow Valley area, which are in descending order:

Kootanie Group	(Cretaceous Coal-bearing Series)[1]
Limestone Series	(Carboniferous and Devonian)

Later, McConnell (1887) studied this area in more detail and recognized four major divisions. In descending order, these are:

Cretaceous of the Cascade Trough	(Cretaceous)
Banff limestone group	(Devono-Carboniferous)
Intermediate limestone	(Devonian)
Castle Mountain group	(Cambrian)

(1) Terms given in parentheses are the suggested ages for each separate stratigraphic unit.

He subdivided the Banff limestone group into:

Upper Banff shale
Upper Banff limestone
Lower Banff shale
Lower Banff limestone

In 1907, after a study of the Cascade Coal Basin to the east of Bow Valley area, Dowling outlined the Upper Palaeozoic succession as follows:

Upper Banff shale	(Permo-Triassic)
Rocky Mountain quartzite)	
Upper Banff limestone)	(Carboniferous)
Lower Banff shale)	
Lower Banff limestone)	
Intermediate limestone	(Devonian)

Dowling separated McConnell's (1887) Upper Banff limestone and introduced the term "Rocky Mountain quartzite" for the upper part. Dowling did not specify a type locality for the Rocky Mountain quartzite. It is believed by P.S. Warren (personal communication) that this term was originated by McConnell(1885) in a report on southern Saskatchewan, in which he described pebbles of Miocene conglomerate as being "derived from Cambrian quartzites of the Rocky Mountains."

The next work in the Bow Valley area was done in 1910 by Shimer, who undertook to determine more definitely the ages of the various formations below the Upper Banff shale. He (1913) subdivided Dowling's Upper Palaeozoic as follows:

Upper Banff shale	(Permian)
Rocky Mountain quartzite)	(Pennsylvanian)
Upper Banff limestone)	
Lower Banff shale	(Mississippian)
Lower Banff limestone)	(Devonian)
Intermediate limestone)	

J.A. Allan (1914) described the "Rocky Mountain Section between Banff, Alberta and Golden, B.C., along the Canadian Pacific Railway" and followed Dowling's 1907 division of the Carboniferous.

In 1924, E.M. Kindle attempted to clarify Palaeozoic nomenclature in the Banff area by introducing a revised set of formational names. This revision overcame the confusion caused by the multiple use of the term "Banff" in describing Upper Palaeozoic strata. His standard Palaeozoic section of the Rocky Mountains near Banff, Alberta was as follows:

Spray River formation	(Triassic)
Rocky Mountain quartzite) Rundle limestone)	(Pennsylvanian)
Banff shale	(Mississippian)
Banff limestone and dolomite	(Devonian)

Kindle recognized Triassic fauna in the Upper Banff shale (Lambe & Kindle, 1916) and named these beds the Spray River formation. The north end of Mount Rundle was designated as the type section of the Rundle limestone. The term "Banff shale" was restricted to Mississippian strata below the Rundle and above the "Banff limestone and dolomite".

In 1925, Shimer revisited the Lake Minnewanka area and revised (Shimer, 1926) Kindle's (1924) classification. He adopted Kindle's formational names but restricted the term "Banff formation" to the original Lower Banff shale. He named the Banff limestone and dolomite (of Kindle, 1924) the "Minnewanka formation". Also, he dated the Rocky Mountain quartzite as Permian. The Rundle formation, formerly Pennsylvanian, was dated both Pennsylvanian and Mississippian.

Shimer's succession was as follows:

Spray River formation	(Triassic)
Rocky Mountain quartzite	(Permian)
Rundle formation	(Pennsylvanian and Mississippian)(1)
Banff formation	(Mississippian)
Minnewanka formation	(Devonian)

The section along the north side of Devil's Gap was designated as the type locality for the Minnewanka limestone. A type locality for the Banff formation was not designated by Shimer, but it is presumably a section on Mount Inglismaldie (Fox, 1953). Beales (1950) claimed that, since Shimer accepted Kindle's terminology, he automatically reverted his sections to the Banff area, and hence, Beales placed the Banff type section on Mount Rundle.

Warren (1927), in his study of the Banff area, accepted the formational nomenclature introduced by Kindle (1924) and Shimer (1926) but qualified the ages of some of the formations. He concluded that all Rundle could be considered Mississippian, but due to Shimer's findings at Minnewanka, the upper beds of the Rundle were questionably referred to the Pennsylvanian. He considered the Rocky Mountain to be Pennsylvanian, but suggested that the uppermost beds may be Permian.

Warren's section of Bow Valley strata was as follows:

Spray River formation	(Triassic)
Rocky Mountain quartzite	(Pennsylvanian)
Rundle formation	(Pennsylvanian (?) and Mississippian)
Banff formation	(Mississippian)
Minnewanka formation	(Devonian)

A few years later, the Carboniferous succession of the Jasper

(1) The Mississippian portion is essentially the Livingstone formation and the Pennsylvanian essentially the Mount Head formation of present day nomenclature.

area was studied by Raymond (1930) and divided as follows:

Rocky Mountain quartzite	(?Pennsylvanian)
Moosehorn limestone Bedson limestone	(Mississippian)

The Moosehorn limestone, as introduced by Raymond, appears to have included both the Banff and Rundle formations (Lang, 1946, p. 19). The Bedson limestone was probably Devonian in age and equivalent to the Palliser, though Raymond included it in Mississippian.

Allan, Warren and Rutherford (1932) noted that the Carboniferous succession at Jasper corresponded to that at Banff, although they concluded that Upper Mississippian was absent. The Rocky Mountain quartzite was correlated lithologically to that of the Banff area and accordingly, was dated Pennsylvanian. The Jasper section was as follows:

Rocky Mountain quartzite	(Pennsylvanian)
Rundle formation	(Lower Mississippian)
Banff formation	(Lower Mississippian-Kinderhookian)

In 1937, after a study of the Bow Gap area, Warren recognized two divisions in the Banff formation. The basal black shales were named the Exshaw formation, the type section of which is on Jura Creek, near the town of Exshaw (See Plate 2, Figure 2, p. 31). The term Banff was applied to the upper calcareous beds. Some confusion has surrounded the age interpretations of these Exshaw shales. Warren considered them to be Upper Devonian although some geologists (Fox, 1951, Crickmay, 1952/ Raasch, 1956a) are of the opinion that a Mississippian age is more probable. Originally, these

TABLE I

STRATIGRAPHIC NOMENCLATURE UP TO 1947

BOW VALLEY AREA										JASPER AREA	
Bow Valley Area Section	DAWSON (1886)	McCONNELL (1887)	DOWLING (1907)	SHIMER (1913)	KINDLE (1924)	SHIMER (1926)	WARREN (1927)	WARREN (1937)	BEACH (1943)	RAYMOND (1930)	ALLAN, WARREN & RUTHERFORD (1932)
Mesozoic	Kootanie Group	Banff limestone (Devono-Carboniferous): Upper Banff shale	Upper Banff shale (Permian ?)	Upper Banff shale (Permian)	Spray River formation (Triassic) *	Spray River formation (Triassic)	Spray River formation (Triassic)			(1)	
Rocky Mountain	Limestone Series (Carboniferous and Devonian)	Upper Banff limestone	Rocky Mountain quartzite (Carb.) *	Rocky Mountain quartzite (Penn.)	Rocky Mountain quartzite (Penn.)	Rocky Mountain quartzite (Permian)	Rocky Mountain quartzite (Penn.)	Rocky Mountain quartzite (Penn.)	Rocky Mountain quartzite (Penn.)	Rocky Mountain quartzite (Penn.?)	Rocky Mountain quartzite (Penn.)
Rundle			Upper Banff limestone (Carb.)	Upper Banff limestone (Penn.)	* Rundle limestone (Penn.)	Rundle formation (Miss. & Penn.)	Rundle formation (Penn.? & Miss.)	Rundle formation (Middle & Upper Miss.)	Rundle formation (Miss. & ?Penn.)	Moosehorn limestone (Miss.)	Rundle formation (Lower Miss.)
Banff		Lower Banff shale	Lower Banff shale (Carb.)	Lower Banff shale (Miss.)	Banff shale (Miss.)	* Banff formation (Miss.)	Banff formation (Miss.)	Banff formation (Lower Miss.)	Banff formation (Miss.)		Banff formation (Lower Miss. Kinderhookian)
Exshaw								Exshaw fm. * (Upper Dev.)			
Devonian		Lower Banff limestone; Intermediate limestone (Devonian)	Lower Banff limestone (Carb.); Intermediate limestone (Devonian)	Lower Banff limestone (Devonian); Intermediate limestone (Devonian)	Banff limestone and dolomite (Devonian)	Minnewanka formation (Devonian)	Minnewanka formation (Devonian)	Minnewanka formation Upper & Middle Dev.)		Bedson limestone (Miss.)	

(1) Note: See text regarding confusion of correlation - pp. 13 - 14.

* Actual type section designation.

shales were placed by Allan (1914) in the Jurassic, based upon fossils identified by P.E. Raymond. Accordingly, Allan named the creek Jura Creek.

Warren's section at Bow Gap was as follows:

Rocky Mountain quartzite	(Pennsylvanian)
Rundle formation	(Middle and Upper Mississippian)
Banff formation	(Lower Mississippian)
Exshaw formation	(Upper Devonian)
Minnewanka formation	(Upper and Middle (?) Devonian)

Beach (1943), in the Moose Mountain Map-area, accepted Warren's (1927) nomenclature but dated the Rundle as both Mississippian and (?) Pennsylvanian.

Development Of Nomenclature After 1947

(a) Bow Valley Area

In the spring of 1947, Beach, in an oral communication to the Alberta Society of Petroleum Geologists, introduced a subdivision of the Rundle formation into:

	(Tunnel Mountain member
Rundle formation	(Shunda member
	(Dyson Creek member

This communication remains unpublished and hence, the division names of the Rundle are not valid. However, geologists have applied these terms in various parts of Alberta to represent beds of different stratigraphic position in the Mississippian and consequently, they have appeared in geological literature. As a result, considerable confusion has arisen over the use of such terms as "Tunnel Mountain",

"Shunda" and "Dyson Creek". According to Beach (See Lexicon of Geologic Names of Alberta), the type sections of the Dyson Creek and Shunda members are listed as at Sheep Mountain in the Dyson Creek Map-area (Hage, 1943) and in the vicinity of Carrot Creek in the Fairholme Range, near Canmore, respectively.

Warren (1947), in an abstract, subdivided the Rocky Mountain formation at Banff into an Upper member of probable Permian age and a Lower member, probably Pennsylvanian. The terms "Norquay Mountain member" and "Tunnel Mountain member", presented orally to the Geological Society of America to represent the Upper and Lower members respectively, were not published in the abstract, but did gain popular usage. Warren(1) withheld publication of this paper pending further proof of the Permian age of the Norquay Mountain member. The identification of a shark's tooth as Permian was upheld by H.E. Wheeler of Washington State University, but was withdrawn shortly after. Several years later, after considerable work on the Permian, Wheeler traced the phosphate beds of the Norquay Mountain member south into the Permian "Phosphoria formation" of Montana and Utah. He also agreed with the identification of the shark's tooth as the genus <u>Helicoprion</u> of Permian age. Therefore, in 1956 Warren (1956b) published his original paper, partially revised due to further work in the Banff area, stating his ideas as to ages and subdivisions of the Rocky Mountain formation. Usage of the terms "Norquay Mountain member" and "Tunnel Mountain member", as defined by Warren later, appeared in literature by Beales (1950),

(1) Dr. P.S. Warren - personal communication.

Douglas (1953) and Fox (1953).

In 1949, Clark, after a study of the Front Range near the Bow River, subdivided the Rundle, Banff and Exshaw formations. His report was the first published reference to Beach's Rundle subdivision presented orally in 1947. Clark divided the Upper Palaeozoic as follows:

(Permian & Pennsylvanian)	- Rocky Mountain formation		
(Mississippian)	(Rundle formation	(Upper	(Upper member
			(Shunda member
		(Lower	(Dyson Creek member
	(Banff formation		(Upper shale member
			(Middle limestone member
			(Lower shale member
(Devonian)	- Exshaw formation		(Exshaw limestone
			(Exshaw shale

Beales (1950) restudied the Banff area and presented detailed descriptions of the Upper Palaeozoic for clarification and use in problems of regional correlations and facies changes. He redescribed type Banff, type Rundle and type Rocky Mountain formations but made no attempt at correlation other than by reference to the large map-units generally employed. In this report, Beales acknowledged Warren's (1947) subdivision of the Rocky Mountain formation and since this is the first published reference to Warren's terms, Beales is credited with the authorship of the term "Tunnel Mountain member" (See Lexicon of Geologic Names of Alberta). He considered the Exshaw to be Mississippian because of its stratigraphic relationship

to the overlying Banff. Beales retained the type section of the Banff formation on Mount Rundle but transferred the Rundle type section to Tunnel Mountain. The Rocky Mountain type section was retained on Tunnel Mountain.

The classification of post-Devonian Palaeozoic formations of the southern Canadian Rockies, as given by Beales, is:

Rocky Mountain formation	(Permian and (?) Pennsylvanian)
Rundle formation	(Mississippian and (?) Pennsylvanian)
Banff formation	(Mississippian)
Exshaw formation	(Mississippian)

Harker (1952), in an abstract, recognized a three-fold stratigraphic and faunal division of the Carboniferous of the Canadian Rockies extending from the Western United States beyond the Yukon-Alaska boundary. He believed the Banff-Rundle contact to be diachronic. He listed the formations as follows:

Rocky Mountain formation	(Upper - (Permian ?) (Lower - (Pennsylvanian)
Rundle formation	(Upper - (Chesterian) (Lower - (Uncertain)
Banff formation	(Kinderhookian and Osagean)

Warren (1956a) discussed the controversy regarding the age of the Exshaw shale and showed that at the type locality, the Exshaw shale is in all probability Upper Devonian. He suggested transgressive overlap of the incoming sea on top of the eroded Palliser formation to explain differences elsewhere in age of this shale.

Later in the same year, at Highwood Pass of the Misty Range, southeast of Banff, Raasch (1956b) proposed to raise the Rocky Mountain formation to group status, containing Storm Creek and Norquay formations, both of Permian age. Storm Creek formation was the term given by Raasch (1954) to strata overlying the Norquay formation found in the Highwood Pass area. The Tunnel Mountain formation of Beales (1950) is dated as Chesterian and placed in the Upper Rundle. Raasch claimed that no Pennsylvanian rocks exist in either the Highwood Pass or Banff areas and that an unconformity has embraced all Pennsylvanian and one-third Permian time. He listed the succession as follows:[1]

Spray River formation	(Triassic)	
Rocky Mountain group	(Storm Creek formation) (Norquay formation)	(Permian)
Rundle group	(Tunnel Mountain formation (Mount Head formation (Livingstone formation	(Chesterian) (Meramecian) (Osagean)
Banff formation	(Kinderhookian)	

In 1956, after a lapse of nine years, Warren published his paper regarding the Rocky Mountain formation of the Banff area. He (1956b) subdivided the Rocky Mountain formation into two members as follows:

Rocky Mountain formation	(Norquay Mountain member - (Permian) (Tunnel Mountain member - (Pennsylvanian)

The latest study by Douglas (1957) in Geology and Economic Minerals of Canada shows the Carboniferous and Permian succession

(1) This table is the work of the author as determined from Raasch's (1956) paper.

in the Rocky Mountains and Foothills as follows:

Rocky Mountain formation	(Permian and (?) Pennsylvanian)
Rundle group	(Etherington formation - (Chesterian) (Mount Head formation - (Meramecian) (Livingstone formation - (Osagean)
Banff formation	(Kinderhookian)
Exshaw formation	(Mississippian or Devonian (?)

(b) Wapiti Lake Area, British Columbia

Laudon et al (1949), in a study of the Wapiti Lake area, British Columbia, recognized a three-fold division for the Carboniferous. In ascending order, these are the Banff, Dessa Dawn and Rundle formations. His Dessa Dawn, a new formation, and Rundle correspond approximately to the upper part of the Banff, and all the Livingstone and Mount Head. His Dessa Dawn formation, a mixture of shale and limestone beds, probably correlates with the upper Banff and Livingstone as recognized in the south. He restricted the Rundle to include beds approximately correlative with the Mount Head. Laudon subdivided his Mississippian section as follows:

Rundle formation (restricted)	(Meramecian)
Dessa Dawn formation	(Kinderhookian)
Banff formation	(Kinderhookian)

(c) Turner Valley Area

Gallup (1951), in describing the subsurface strata of the Turner Valley oil and gas field, used Beach's (1947) subdivisions for the Rundle. He divided the Tunnel Mountain formation into two

members. He indicated that the Shunda formation was equivalent to the "Black Lime" of subsurface. His Mississippian succession was as follows:

Rundle	(Tunnel Mountain formation	(Upper member (Turner Valley member
	(	
	(Shunda formation ("Black Lime")	
	(Dyson Creek formation	
Banff formation		

(d) Jasper Area

After detailed work in Jasper Park, Brown (1952) introduced the term Greenock formation to describe Upper Mississippian and Lower Pennsylvanian strata. He raised Raymond's (1930) term "Moosehorn formation" to group status embracing all the Carboniferous as follows:

	(Greenock formation	(Upper Member (Middle Member (Lower Member	Pennsylvanian (?) - Chesterian and Meramecian
	(		
Moosehorn group	(Rundle formation		- Meramecian and Osagean
	(		
	(Banff formation	(Upper Member (Lower Member	- Kinderhookian

Raasch (1956) recognized Brown's three-fold division of the Greenock formation and stated that the Lower member is equivalent to the Tunnel Mountain formation to the south. He suggested the following ages for the Greenock:

Greenock formation	(Upper Member) (Middle Member)	(Permian)
	(Lower Member)	(Chesterian)

(e) Sunwapta Pass Area

Spreng (1953), at Sunwapta Pass, used Warren's (1927) Mississippian nomenclature with modifications by Laudon et al (1949). His section was as follows:

Rundle formation (restricted) Dessa Dawn formation	(Mississippian)
Banff formation	(Kinderhookian)
Exshaw formation	(Upper Devonian)

(f) Mount Head - Highwood Pass Area

Douglas (1950a), in the Gap Map-area, recognized four divisions in the Rundle which he designated as follows:

Rocky Mountain quartzite	(Pennsylvanian)	
Rundle formation	(Member D (Member C (Member B (Member A	(Pennsylvanian (?) and Mississippian)
Banff formation	(Mississippian)	

Later, Douglas (1953) revised the nomenclature for Carboniferous strata of the southern Alberta foothills as exposed in the Mount Head Map-area and the Livingstone and Highwood Ranges. He recognized the old three-fold Carboniferous divisions - Banff, Rundle and Rocky Mountain but raised the status of the Rundle to group and subdivided the Rundle and Rocky Mountain as follows:

Rocky Mountain formation	(Upper part (Etherington member

Rundle group	Mount Head formation	Carnarvon member
		Marston member
		Cummings member
		Salter member
		Baril member
		Wileman member
	Livingstone formation	Turner Valley member
		Pekisko member

Banff formation

He introduced the term "Etherington member" for the lower part of the Rocky Mountain formation and correlated it lithologically with type Tunnel Mountain. Raasch (1956b) claimed that the lower part of type Rocky Mountain is Upper Mississippian and hence, called the Etherington formation Chesterian in age. Norris (1957) dated the Etherington as Chesterian, correlative with the lowermost beds of the Tunnel Mountain and Upper Rundle at Banff. Later, Douglas (Bostock, Mulligan and Douglas, 1957) placed the Etherington formation in the upper part (Chesterian) of the Rundle group, apparently equivalent to the 200 feet directly below type Tunnel Mountain.

Raasch (1954) published a private report on the Highwood Pass area south of Banff and divided the Permo-Carboniferous section as follows:

	Storm Creek formation	(Permian or Pennsylvanian)
Rundle group	(Tunnel Mountain formation	(Chesterian)
	(Mount Head formation	(Meramecian)
	(Livingstone formation	(Osagean)

He introduced the Storm Creek formation, the lower part

of which was considered equivalent in age to type Norquay. He redefined the term Tunnel Mountain to emcompass all strata of Chesterian age. According to this new definition, the Tunnel Mountain formation would include the lower 57 feet of type Norquay, all of type Tunnel Mountain, and the upper 191 feet of type Rundle.

Later, Raasch (1956) recognized lithological equivalents of type Norquay in the Highwood Pass section and proposed raising the Rocky Mountain to group status containing the upper Storm Creek and lower Norquay formations, both of Permian age. The Storm Creek formation includes Permian strata younger than that present at Banff. Raasch's modification of the Highwood Pass section was as follows:

Rocky Mountain group	(Storm Creek formation (Norquay formation	(Permian)
Rundle group	(Tunnel Mountain formation (Mount Head formation (Livingstone formation	(Chesterian) (Meramecian) (Osagean)

Norris (1957) studied the Rocky Mountain succession at Beehive Pass in the High Rock Range, south of the Highwood Pass area. He recognized two units in the Rocky Mountain formation, which are:

Rocky Mountain formation	(Upper unit (Todhunter member
Rundle group	(Etherington member

He presented a tentative correlation in which his Upper unit is equivalent to the Storm Creek member at Highwood Pass and also

correlative with the upper half of Warren's type Tunnel Mountain member. He also correlated the Todhunter member with the lower part of Raasch's "Norquay member" at Storm Creek and with the middle beds of type Tunnel Mountain.

A lithologic correlation as an alternate to Raasch's was also presented, in which the upper unit at Beehive Pass and the Storm Creek member at Highwood Pass are correlative and possibly equivalent to type Norquay. Hence, he considered it would not be necessary to postulate the existence of new Permian beds in the Misty and High Rock Ranges younger than any Palaeozoic strata in Bow Valley.

Raasch (1958), after more detailed work at Highwood Pass and with supplementary data from the nearby King Creek section, presented a more detailed subdivision of the Upper Palaeozoic section at Highwood Pass. The succession is as follows:

Rocky Mountain group (Permian)	(Storm Creek formation	
	(Norquay formation (Leonard or Word)	(Member 1 (Member 2 (Member 3
Rundle group (Mississippian)	(Tunnel Mountain formation (Chesterian)	(Member 1 (Member 2 (Member 3 (Member 4
	(Mount Head formation (Meramecian)	(Member 1 - Carnarvon (Member 2 - Marston (Member 3 - Loomis (Member 4 (Member 5
	(Turner Valley formation (Osagean)	(Mount Rae member (Misty member (Elkton member
	(Shunda formation (Osagean)	
	(Pekisko formation (Osagean)	

(g) Nordegg Area

Douglas (1956) listed the Carboniferous succession at Nordegg, Alberta, as follows:

	Spray River formation	(Triassic)
	Rocky Mountain formation	(Pennsylvanian (?)
Rundle group	(Mount Head formation (----unconformity---- (Livingstone formation	(Mississippian)
	Banff formation	(Mississippian)
	Exshaw formation	(Devonian)

Although the term Shunda had been previously extensively used, it was not until 1956 that the type section was first formally described.

Stearn (1956) described the type section of the Shunda formation which is located along an unnamed creek tributary to Shunda Creek at its gap through the Brazeau Range. Neither the upper contact of the Rundle nor the lower contact of the Banff is exposed. Stearn placed the Shunda stratigraphically as follows:

Rundle group	(Dolomite and limestone beds (Shunda formation (Pekisko formation
	Banff formation

This summary history of Carboniferous nomenclature concludes with the status of nomenclature up to the present.

Bow Valley Area, Alberta

	Bow Valley Area Section		BEACH (1947) (unpublished)		WARREN (1947) (unpublished)		CLARK (1949)			BEALES (1950)	HARKER (1952) (abstract)		WARREN (1956b)	
					Mesozoic		Mesozoic			Mesozoic	Mesozoic		Mesozoic	
Permian	Rocky Mountain	Norquay Mountain member	Undescribed		Rocky Mountain formation	Norquay Mountain* member (Perm.)	Rocky Mountain formation (Perm. & Penn.)			Rocky Mountain formation (Perm. & ?Penn.)	Rocky Mountain formation	Upper (Perm.?)	Rocky Mtn. fm.	Norquay Mtn. mb. (Perm.)
Pennsylvanian		Tunnel Mountain member				Tunnel Mountain* member (Penn.)						Lower (Penn.)		Tunnel Mtn. mb. (Penn.)
Chesterian	Rundle	Etherington equivalents	Rundle formation	Tunnel Mountain member	Undescribed		Rundle fm.	Upper	Upper member	Rundle formation (Miss. & ?Penn.)	Rundle formation	Upper (Chester)	Undescribed	
Meramecian ?		Mount Head equivalents		Shunda member					Shunda member			Miss.		
Osagean ?		Livingstone equivalents		Dyson Creek member				Lower	Dyson Creek member					
Kinderhookian	Banff	Upper member / Middle member / Lower member	Undescribed				Banff fm.	Upper shale mb / Middle ls. mb. / Lower shale mb		Banff formation	Banff formation (Kinderhookian & Osagean)			
Devonian	Exshaw						Exshaw fm.	Exshaw ls. / Exshaw shale		Exshaw formation				

* Type Section Designation

STRATIGRAPHIC NOMENCLATURE AFTER 1947

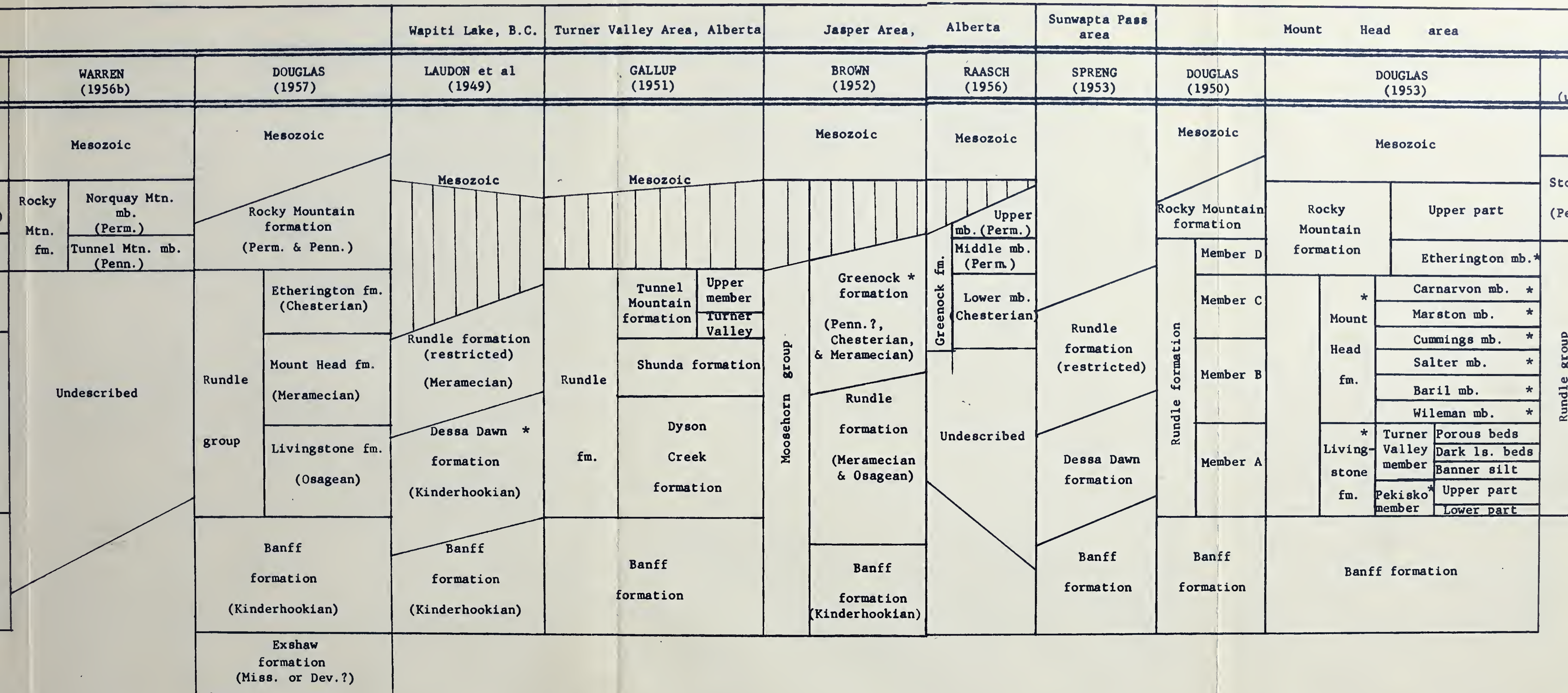


TABLE 2

										Nordegg area, Alberta				Thesis Area	
	RAASCH (1954) (unpublished)		RAASCH (1956)		NORRIS (1957)		RAASCH (1958?)			DOUGLAS (1956)		STEARN (1956)		PRESENT WRITER	
	Mesozoic		Mesozoic		Mesozoic					Mesozoic					
t	Storm Creek fm. (Perm. or Penn.)		Rocky Mountain group	Storm Creek (Perm.) Norquay fm. (Perm.)	Rocky Mountain fm.	Upper unit Todhunter mb	Rocky Mountain group (Perm.)	Storm Creek formation Norquay formation	Member 1 Member 2 Member 3	Rocky Mountain formation (Penn.)		undescribed		Tunnel Mountain formation (Penn. & Chesterian)	
n mb.* b. * *	Rundle group	Tunnel Mtn formation (Chesterian)	Rundle group	Tunnel Mtn. formation (Chesterian)	Rundle group	Etherington formation	Rundle group (Mississippian)	Tunnel Mountain formation (Chesterian)	Member 1 Member 2 Member 3 Member 4	Rundle group (Mississippian)	Mount Head formation			Rundle formation	Upper member (Meramecian)
. * * * *		Mount Head formation (Meramecian)		Mount Head formation (Meramecian)				Mount Head formation (Meramecian)	Mb.1-Carnarvo Mb.2-Marston Mb.3-Loomis Member 4 Member 5		unconformity	Rundle group	Dolomite & limestone beds		
eds beds ilt art art		Livingstone formation (Osagean)		Livingstone formation (Osagean)				Turner Valley formation Shunda formation Pekisko formation	Mount Rae mb. Misty mb. Elkton mb.		Livingstone formation		Shunda formation * Pekisko formation		Lower member (Osagean)
										Banff formation (Mississippian)		Banff formation		Banff formation (Kinderhookian & Osagean)	Member D (Shunda) Member C Member B Member A
										Exshaw formation (Devonian)				Exshaw formation (Devonian)	

* Actual type section designation

CHAPTER III

PERMO-CARBONIFEROUS STRATIGRAPHY OF THE ROCKY MOUNTAIN FRONT RANGES

General Stratigraphy

The Upper Palaeozoic sequence of the Front Ranges between Banff and Jasper, Alberta, ranges in age from uppermost Devonian to Permian (?) and consists of the Exshaw, Banff, Rundle and Rocky Mountain formations.

The typical stratigraphic succession of the type section at Banff, the Mount Greenock section at Jasper and the Mount White section of the intervening area, is shown in Figure 3, p. 9 . Formational nomenclature of the type section at Banff, with modifications by the writer, is adopted for this report. The Banff and Rundle formations are subdivided into members at sharp lithologic breaks for greater ease in correlation.

Exshaw Formation

The Exshaw formation, though considered uppermost Devonian in age (Warren, 1933, 1956a) is described in this report since it "appears to belong to the main Mississippian cycle of sedimentation" (Beales, 1950, p. 2). These strata rest paraconformably on the Palliser formation and are overlain conformably by the Banff formation. When exposed, this formation is an excellent horizon marker.

The Exshaw consists of recessive, black, fissile, non- calcareous pyritiferous shale, weathering dark grey to black, with abundant red

to yellow iron oxide staining along fractures (See Plate 2, Figure 2, p. 31). This formation is restricted to the black shales overlying the Palliser formation and is distinguished from the overlying Banff by its black colour and non-calcareous nature. Over most of the area between Bow Valley and the North Saskatchewan River, the Exshaw is overlain by an orange weathering, calcareous siltstone bed, 10 to 25 feet thick. This siltstone bed forms the basal bed of the Banff formation and may be equivalent to the Sappington sandstone of Montana and the middle siltstone bed of the Bakken formation of the Williston Basin.

The recessive nature of the Exshaw formation makes it difficult to determine whether this formation is present in some sections (See Plate 5, Figure 2 , p. 55) This formation does not occur at the Mount Greenock section, but has been reported north of Jasper, in the Brule Range and Wapiti Lake area, B.C. by Lang (1947) and Laudon (1947, 1949) respectively.

This formation is fairly consistent in thickness over the area with very slight thinning to the north. Warren (1937, 1956a) reports 35 feet of Exshaw shale at its type section on Jura Creek. The Exshaw is 33 feet thick on Mount Rundle and 55 feet thick on Mount Norquay with an average thickness[1] for the area north and east of Banff of 30 feet.

Banff Formation

The Banff formation forms the lower shaly sequence of Mississippian

(1) Average thicknesses of formations or members have been determined by an average of all sections reported in this thesis.

DESCRIPTION OF PLATE II

Figure 1: Banff formation exposed on Mount Rundle, showing the ribbed appearance of the interbedded limestones and shales of Member B.

Figure 2: Type section of the Exshaw formation at Jura Creek, near the town of Exshaw, Alberta. Massive bedding plane at the lower right side is the top of the Palliser, and the massive limestones at the top of the picture represent the basal beds of the Banff formation.

strata and is overlain by the massive crinoidal and dolomitic limestones of the Rundle. The repetition of several lithofacies in the Banff formation has been credited to cyclic sedimentation (Spreng, 1953). At type section on Mount Rundle, this formation has been divided by Kindle (1924) and Warren (1927) into three members. A similar division was made by Beales (1950) at Mount Norquay where the three units are better exposed. In descending order, these are as follows:

1. Upper Member - 630± feet of relatively massive limestone and dolomite.
2. Middle Member - 360± feet of relatively resistant, shaly beds.
3. Lower Member - 270± feet of soft, very argillaceous and silty beds with variable calcareous content. A massive bed of sandy siltstone immediately overlies the Exshaw shale.

The Banff formation at Mount Greenock, Jasper, as described by Brown (1952) is probably equivalent to only the two lower members of type Banff. Brown showed the Banff-Rundle contact at Jasper considerably lower and not equivalent to this contact at Banff (See Figure 3 , p. 9 , for correlation). He divided the Banff into two members; a lower shaly member and an upper limy member.

For the intervening area between Banff and Jasper, a subdivision of the Banff formation into four members is proposed See Plate 3, Figure - , p. 34). This subdivision is laterally continuous northward from the North Cascade section to the Greenock section. The four lithofacies of the Banff are, in descending order,

as follows:

1. Member D - dark grey argillaceous limestone, crinoidal in part, with interbeds of dolomitic limestone and calcareous shale.

2. Member C - light grey, massive, crinoidal limestone.

3. Member B - interbedded limestone and shale.

4. Member A - dark grey-brown calcareous shale.

The North Cascade section, some 20 miles north of Banff, is one of the most significant sections of the area, as it was used as a "Pivot point" for correlating the Banff formation. This section shows the transition of Members C and D of the intervening area into the Upper member of type Banff. At this locality, Member C has thinned to approximately 40 feet and is interbedded with dark argillaceous limestones. This section shows the last known outcrop of Member C prior to its pinchout before reaching the Banff type section.

The four members of the Banff formation of the intervening area can be correlated to both the Banff type section and the Mount Greenock section (See Correlation Table, in pocket).

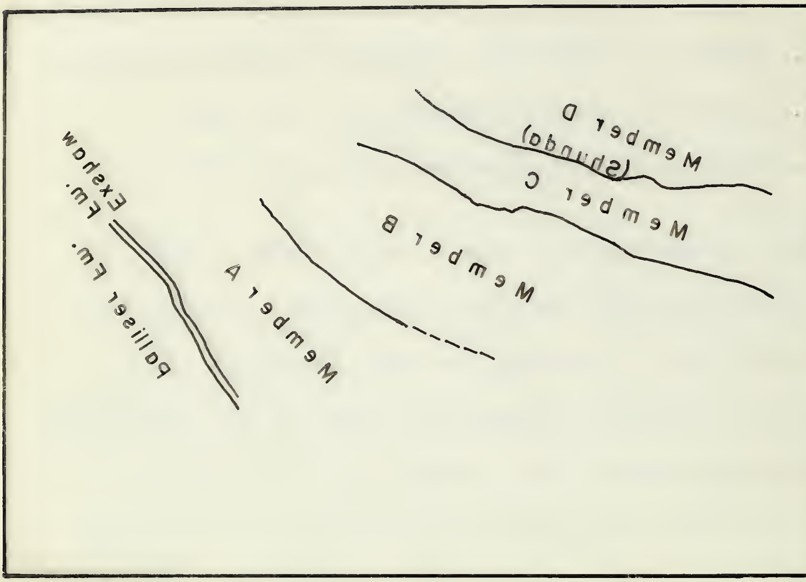
The Banff formation thins northward from 1458 feet at type section to 905 feet at Jasper.

Member A consists of recessive dark grey-brown, dark-grey weathering, fissile calcareous shale with occasional thin orange weathering, silty dolomite interbeds. This unit correlates with the Lower member of type Banff formation (See Correlation Table)

PLATE III

South Ram River section showing the four members of the Banff formation.

PLATE III



South Ram River section showing the four members of the Banff formation.

In the northern half of the area, interbeds of microcrystalline argillaceous dolomite and limestone occur near the top of this unit. From type section northward to the Clearwater River, a basal bed of orange weathering, dolomitic siltstone usually marks the base of this unit. Chert is generally absent.

Although poorly exposed, Member A is present in all sections and can be traced from the Banff area to the Greenock area. With the exception of a few poorly preserved, unidentifiable pelecypods at the top of the basal siltstone bed, this unit is very unfossiliferous. Member A thickens northward. On Mount Rundle, it is 240 feet thick and at Mount Greenock 312 feet thick, with an overall average thickness in the area of 218 feet.

Member B consists predominantly of thin alternating orange-brown weathering limestone and black weathering shale beds that grade into thicker bedded argillaceous limestone with thin shale interbeds in the upper half. This unit is the thickest member of the Banff lithofacies and is consistent, both in thickness and lithology, over the whole area. The upper part of Member B is the most fossiliferous unit of the Mississippian sequence of the present area.

This unit is resistant and has a ribbed pattern in outcrop caused by the alternation of thin beds of different coloured limestone and shale and emphasized by the recessive nature of the shale interbeds (See Plate 2, Figure 1 , p. 31). Member B is a good horizon marker.

The limestone is dark grey to black, cryptocrystalline, hard, dense and becomes cherty towards the upper half of this unit. The chert is black, weathers brown to orange, and occurs as nodules or elongated lenses in the limestone. The shale interbeds are black in colour, calcareous and fissile. This alternation of limestone and shale in beds 2 to 4 inches thick grades into thick bedded, black, medium crystalline argillaceous limestone, crinoidal in part, and fossiliferous. The thick limestone beds are separated by thin (up to 6-inch) beds of fissile, black, calcareous shale.

Member B ranges in thickness from 615 feet at type section to 300 feet at the Greenock section.

Member C is the most resistant and easily recognizable unit of the Banff formation for the area north of Bow Valley. It has been traced from the North Cascade section, where it pinches out, northward to Jasper. Lithological equivalents of this member are not known from type Banff. Stratigraphic relationships on North Cascade indicate that it is equivalent probably to the lower part of type Upper member of the Banff formation. Member C, sometimes called the "Pekisko formation" (Stearn, 1956) is well exposed at Jasper and comprises the lower 188 feet of Brown's (1952) Rundle formation.

Member C consists of light to medium grey, light grey weathering, resistant, cliff-forming, coarsely crystalline, fragmental, crinoidal limestone and has an average thickness of 155 feet. This unit is

DESCRIPTION OF PLATE IV

Figure 1: View of Mount Rundle, with Tunnel Mountain and town of Banff in foreground. Uppermost massive, light grey cliffs are the Rundle formation underlain by the shaly dark grey limestones of the Banff formation.

Figure 2: Mount White section, showing the sharp contact between Members B and C of the Banff formation. This contact has often been assumed to be the Banff-Rundle contact.

fairly consistent in thickness from Jasper to North Saskatchewan River, south of which it thins considerably and disappears before reaching Banff. The North Cascade section shows the pinchout of Member C. No previously known lithologic equivalents of this unit were found in the type section at Banff. Warren (personal communication), however, states that he found a very thin bed of this limestone in the middle part of the Upper member of type Banff.

The uppermost unit of the Banff formation, Member D, consists of dark grey, dark grey weathering, medium crystalline, argillaceous limestone with occasional local beds of light to dark grey, medium crystalline, crinoidal limestone and fine crystalline, medium grey, dolomitic limestones and dolomites. Shale interbeds are locally present. This member is 153 feet thick at Jasper, thickens to 460 feet at North Cascade and grades laterally into the Upper member of type Banff.

This member correlates (See Correlation Table, pocket) with the 212 feet of type Shunda formation (Stearn, 1956) at Shunda Creek near Nordegg, Alberta and will hereafter be termed the "Shunda member" in this report. It is overlain by the basal beds of the Rundle formation.

Rundle Formation

The type section of the Rundle formation, exposed on Tunnel Mountain, consists of approximately 2200 feet of carbonates. Kindle (1924), Warren (1927), and Beales (1950) attempted no subdivision

of the Rundle. Later work (Douglas (1957), Moore (1958) and present writer) shows that a three-fold division of the Rundle can be made at type section, which in descending order is as follows:

Rocky Mountain formation

Rundle Group

1. Etherington formation - 197 feet of light grey, fine grained, hard limestones and dolomites with occasional silty and sandy beds.

2. Mount Head formation - 536 feet of dark grey, dark grey weathering, medium crystalline, argillaceous limestone, crinoidal in part, with recessive interbeds of dark grey, fissile, calcareous shale.

3. Livingstone formation - 1482 feet of resistant light grey, light grey weathering, coarse crystalline, fragmental, crinoidal limestone, with minor dolomitic limestone interbeds.

Banff formation

Away from type section, the Rundle is one of the most widely recognized units of the Carboniferous over much of the Canadian Rockies. It is recognized as far south as Crowsnest Pass, and as far north as Wapiti Lake, occuring also in most sections in the intervening area. The interpretation of the Rundle formation of Mount Greenock has been subject to some ambiguity. The present writer considers that the term Rundle should be restricted to the Upper part of Brown's Rundle formation and the Lower member of his Greenock formation.

The division of the Rundle formation in the present area as proposed in this paper is based on the textural properties of the

limestone. Since the argillaceous content of the Mount Head formation at Banff and southward does not carry into the intervening area between Banff and Jasper, it is not used as a criterion for subdivision. Rather, two types of limestone are predominant; an upper fine crystalline (calcilutitic) phase and a lower coarse crystalline (calcarenitic) phase, which are used as the basis of subdivision as follows:

1. Upper Member - finely crystalline to micro-crystalline limestone grading into dolomitic limestone with occasional silt beds toward the top of the unit.

2. Lower Member - light grey, coarsely crystalline, crinoidal limestone with thin interbeds of dolomitic limestone.

The Lower member, the lateral continuation of the Livingstone formation, is predominantly massive, light grey, light grey weathering, coarsely crystalline, fragmental, crinoidal limestone, with interbeds of medium grey, fine crystalline, thin to medium bedded, dolomitic limestone. Local beds of "birdseye-type" limestone(1) are present in several sections and vary in stratigraphic position in this member. Chert is very abundant, particularly in the dolomitic limestone beds at type section in this member but becomes less abundant northward. At the Greenock section, the Lower member becomes predominantly a dolomitic limestone, with interbeds of crinoidal limestone. This member is 1482 feet thick at type section Rundle, thins rapidly to 348 feet at Jasper and has an average thickness of 718 feet over the area.

(1) "Birdseye-type" limestone is a field term used to describe medium to dark brown, cryptocrystalline limestone containing small irregular patches and "eyes" of clear to white calcite.

The Upper member consists predominantly of medium to dark grey, fine to microcrystalline, medium bedded dolomitic limestone and is the lateral equivalent of the Mount Head formation. This unit is resistant and cliff forming. Scattered chert nodules occur in all sections. "Birdseye-type" limestone, argillaceous limestone and dolomite occur locally as interbeds. This member is 733 feet thick at type section and thins to 467 feet at Jasper. It becomes thinner towards Jasper, probably in part because of convergence of strata and in part because of the tendency for diachronic changes in lithofacies northward and eastward, to silty dolomites, of the Tunnel Mountain formation.

The Upper member is the stratigraphic equivalent of the Mount Head formation at Banff which is very fossiliferous there. This member becomes less fossiliferous northward. However, a geographically widespread productid, Gigantoproductus brazerianus occurs near the top of the unit and is extremely useful in correlation and picking the Rundle-Tunnel Mountain contact.

Tunnel Mountain Formation

The Rocky Mountain formation type section, located on Tunnel Mountain is described by Beales (1951) and Warren (1956). Warren (1947 - abstract; 1956) divided the Rocky Mountain into two members; the upper Norquay Mountain member and the lower Tunnel Mountain member. Type section Tunnel Mountain consists of fine grained dolomite, quartzite and sandy to silty dolomite, whereas the Norquay Mountain

member is composed of fine grained, silty dolomites, bedded cherts, quartzites, cherty dolomites and phosphate beds. The Norquay Mountain member is very limited in lateral extent both north and east of Banff. At Lake Minnewanka, 10 miles east of type section, only 7 feet of this member is present (Warren, 1956b).

The Tunnel Mountain member and possibly some Norquay Mountain member occur in the present area. However, in this thesis, strata, composed of silty dolomites and dolomitic sandstones, resting on the Rundle limestone, are correlated with type Tunnel Mountain member and are called the Tunnel Mountain formation. This sequence is correlated with the Upper and Middle members of Brown's Greenock formation at Jasper (See Figure 3 , p. 9).

The Tunnel Mountain formation consists of predominantly light blue grey, light grey weathering, hard, dense, silty to sandy dolomite, with dolomitic siltstone and sandstone interbeds. A massive chert bed, ranging from 5 to 20 feet thick is present as the uppermost bed of this formation in many of the sections and could possibly be Norquay Mountain member equivalents. Local finely crystalline limestone and dolomite beds are present in some sections. Generally, two thin beds of grey to green, possibly bentonitic, shale occur in the lower beds of this formation and are extremely useful horizons for correlation. These shale beds are usually very recessive and often covered.

The Tunnel Mountain formation, though present in all sections,

is quite variable in thickness over the area. This formation thins from 615 feet at type section to 200 feet in thickness at the Greenock section and has an average thickness of 316 feet. It is unconformably overlain by the Triassic Spray River formation and the variability in thickness of the Tunnel Mountain is due probably to the irregular erosion surface of its upper boundary.

The contact relationships of the Rundle and Tunnel Mountain formations are variable over the area. In general, the lower boundary of the Tunnel Mountain has been placed where silty dolomites become predominant over the fine crystalline limestones of the Upper member of the Rundle formation. A change in weathering colour is also evident where the light grey limestones grade into light brown, silty dolomites. This contact is subject to diachronism and tends to become older north and east of Bow Valley. At Banff, the Tunnel Mountain rests on Chesterian carbonates of the Rundle and is therefore late Chesterian or more probably Pennsylvanian. At Lake Minnewanka and northward to the Clearwater River, it rests on Meramecian as indicated by the presence of Gigantoproductus brazerianus shortly below the associated green shales of the lower Tunnel Mountain. North of the Clearwater River, absence of fauna makes age relationships of the contact more difficult. However, the presence of the green shales in the middle of the Tunnel Mountain formation at the South Ram River section strongly suggests that the contact is becoming considerably older northward.

CHAPTER IV

CORRELATION

Conformable relationships of the succession embracing the Exshaw, Banff, Rundle and Tunnel Mountain formations, exist in all sections studied in the present area. In general, formations are easily distinguished, but conformable habit of the strata often makes exact definition of contacts difficult.

Correlation of strata is based primarily on lithology and stratigraphic position, though faunal evidence given by Dr. S.J. Nelson is used to supplement the former information.

Exshaw Formation

The Exshaw formation, as exposed in the present area south of Clearwater River, easily correlates both lithologically and by stratigraphic position with type Exshaw. North of the Brazeau River section to Jasper, Exshaw lithofacies are apparently absent. It has been reported however, in sections north of Jasper in the Brule Range (Lang, 1946) and in the Wapiti Lake area (Laudon et al, 1949).

The age of the Exshaw is disputed. Some geologists (Fox, 1951; Crickmay, 1952/ Pamenter, 1956) consider it Lower Mississippian; while others (Warren, 1937; 1956a) place it in Upper Devonian. Because of the unfossiliferous nature of the unit in the present area, supplementary evidence as to its age is not available.

Banff Formation

The Banff formation of the present area correlates almost in toto with type Banff, although lateral variations in lithology often make recognition of its component members difficult. The upper boundary of the Banff in this area and the Jasper area is placed at the top of Member D (Shunda formation of Stearn, 1956). This usage differs from that of previous workers (Stearn, 1956, Brown, 1952) who placed the top of the Banff at the top of Member B and included the light-coloured, fragmental limestones of Member C (Pekisko formation of Stearn, 1956, lower part of Rundle of Brown, 1952) in the basal Rundle. The present writer prefers to raise the limits of the Banff to include the Shunda member, so that the predominantly argillaceous sequence will be placed within the Banff, and thus the Rundle, as redefined in this area, will be laterally continuous with type Rundle (see also Moore, 1958a).

Member A, the lowest unit of the Banff formation, clearly correlates both on stratigraphic position and by lithology with type Lower Banff. It is also the correlative of Brown's (1952) Lower member of the Banff formation in the Jasper area.

Member A is almost completely unfossiliferous. At Mount White, a few very poorly preserved, unidentified pelecypods were found in the basal siltstone. This member is considered to be probably Kinderhookian in age because of its position with respect to the fossiliferous Member B. Harker and Raasch (1958) also

support this Kinderhookian age of the lowermost Banff of subsurface.

Member B, because of its striking rhythmic alternation of limestone and shale, is easily recognized from Banff to the Jasper area. It correlates with the Middle member of type Banff and with Brown's Upper member of the Banff formation in the Jasper area.

Particularly in the upper beds, Member B is the most fossiliferous unit of the Mississippian succession in the southern Canadian Rockies. Lithostrotionella jasperensis Kelly, Linoproductus ovatus (Hall), Dictyoclostus gallatinensis (Girty), Dictyoclostus arcuatus (Hall), Productella sp., cf. P. pyxidata (Hall), Rhynchotreta elongata var. usheri Brown, Platyrachella rutherfordi (Warren), Spirifer esplanadensis Brown, Spirifer albertensis Warren, Composita humilis (Girty), Composita athabaskensis Warren, Dielasma chouteauensis Weller, and Cliothyridina lata Shimer are the most abundant and characteristic elements of the fauna. Although most of this fauna is indigenous to the Mississippian of western North America, the few forms such as Dielasma chouteauensis and Dictyoclostus arcuatus that do occur in type Mississippian are confined to the Kinderhookian stage and suggest a corresponding position for Member B.

The above fauna is generally more characteristic of this member north of Banff. At Banff, this member is less fossiliferous. The section at North Cascade is very important in that it equates Member B of the present area with the type Middle member of the Banff section.

Member C, an easily-recognizable, resistant, light-coloured,

fragmental, crinoidal limestone unit, occurs in the present area and Jasper area, but is absent at Banff. At Jasper, by reason of its lithology, this unit was placed by Brown (1952) in the lower part of the Rundle formation. Similarly, Stearn (1956), in the Nordegg area, has called this member the Pekisko formation and included it in basal Rundle. As stated previously (pp.36-38), the present writer is including this member in the Banff formation.

This member thins to the south and was found to pinch out at the North Cascade section. The pinchout position here suggests that the member is coeval with the lower part of type Upper Banff and faunal associates suggests an Osagean age.

Distant correlatives of Member C are uncertain. The stratigraphic succession in the nearby Sundre-Harmattan-Elkton fields (See Penner, 1957, pp. 101-104) of the Interior Plains suggests that Member C is equivalent to beds there termed Pekisko formation. However, it is not known if Member C is the lateral continuant of type Pekisko. Problems of Pekisko correlation are discussed at greater length on page 56.

Member D is correlated with the type Shunda formation of the Nordegg area (see Stearn, 1956, pp.237-239) and is here called the Shunda member and included in the Banff formation. The Nordegg succession described by Stearn (ibid.) consists, in ascending order, of the Banff, Pekisko and Shunda formations. The lithology, as well as the fauna, of his Banff formation indicates that it correlates

with Member B of this paper. Thus, his Pekisko and Shunda, by virtue of their stratigraphic position and lithology, correspond to Members C and D, respectively, of this paper.

At Jasper, lithologic equivalents of the Shunda member occupy 153 feet of beds above Member C, extending from 752 feet to 905 feet above the base of Brown's (1952) Mississippian succession, and correspond approximately to the middle of his Rundle formation.

The Shunda member of the present area is correlated with most of type Upper Banff because of its stratigraphic position and fauna. In general, the Shunda fauna is distinct from that of type Upper Banff. These two faunas, however, were found to intermingle in the Shunda member of the North Cascade section.

The Shunda has two faunal zones. The lower one contains *Lithostrotionella micra* Kelly, *Spirifer forbesi* Norwood and Pratten and *Spirifer minnewankensis* (Shimer). The upper zone contains *Lithostrotion mutabile* (Kelly), *Spirifer minnewankensis* (Shimer), *Spirifer grimesi* Hall, *Spiriferella plena* (Hall), and *Syringothyris textus* (Hall). The above two faunas suggest that the Shunda member and most of type Upper Banff are Osagean in age.

Rundle Formation

The Rundle of the present area can easily be correlated as a unit with the Rundle group of Banff and more southern areas. However, correlation with component formations of that group is

difficult because of rapid lateral variation in lithofacies within the present area. Thus, the unit in this area will be referred to as a formation.

The Banff-Rundle contact is not considered strongly diachronic. Meagre faunal evidence suggests that it is either approximately of the same age throughout the Banff-Jasper area, or that it may become slightly older north of Clearwater River. The approximate constancy of thickness of the Banff formation over the Banff-Jasper area also suggests stability of the Banff-Rundle contact.

In contrast to its lower boundary, the upper boundary of the Rundle is thought to be rather strongly diachronic. At Banff, the Rundle-Tunnel Mountain boundary is placed at late Chesterian or early Pennsylvanian (Warren, 1956b; Nelson, personal communication). To the east and northwest, in the Lake Minnewanka and present areas respectively, the contact is placed at latest Meramecian or early Chesterian. Meagre faunal and stratigraphic evidence suggests that it may become slightly older toward the Jasper area.

Lower Member

The Rundle of the present area is variable in lithology but generally, two broad lithologic divisions, here called members, can be recognized. The Lower member consists of light-coloured crinoidal limestones and dolomites and roughly correlates with the Livingstone formation at Banff. The lower 330 feet of the present

writer's Rundle at Jasper belong to this member and occupy most of the upper part of Brown's (1952) Rundle formation.

This member and the correlative Livingstone formation are very unfossiliferous but are thought to be Osagean in age. This dating was done for the Livingstone by Harker and Raasch (1958), and it is also suggested (Nelson, personal communication) by the formation's position with respect to the underlying Osagean beds of the Banff and overlying Meramecian beds of the Mount Head.

As stated previously (p. 49), the contact between the Lower member and underlying Banff formation is thought to be approximately coeval from Banff to Jasper. The upper boundary of the Lower member is also thought to be of the same age throughout the area or to become slightly older to the north. This dating is based upon Lithostrotion sinuosum (Kelly), a coral characteristic of Upper Livingstone as exposed at Tunnel Mountain. This species occurs in the lower beds of the Upper member of the Rundle at Mount Greenock.

Since the Lower member is thought to embrace correlatives of most of the Livingstone, its rapid thinning north of Banff may be caused by convergence of strata, suggesting shelf conditions there.

Upper Member

The Upper member of the Rundle consists mainly of dark, finely crystalline dolomitic limestones. Both its stratigraphic position and fauna indicate time correlation to the Mount Head formation of

Banff and southward. Since it does not have typical Mount Head lithology, it is not placed in that formation. At Jasper, the Upper member comprises the upper 467 feet of the present writer's redefined Rundle. This unit embraces the upper 192 feet of Brown's (1952) Rundle and all the Lower member of his Greenock formation.

Although relatively unfossiliferous, the Upper member is thought to be Meramecian in age because of two fossil horizons. The lower one, consisting of Lithostrotion warreni Nelson ms. nom. nud., Lithostrotionella astraeiformis (Warren) and Amygdalophyllum sp., occurs in the middle beds. This assemblage is thought to be part of the Upper Lithostrotionella beds which, farther south, occur in the Lower Mount Head formation and have been dated as Meramecian. The upper faunal horizon generally occurs in the uppermost beds of the Upper member from Clearwater River southward. It contains abundant Gigantoproductus brazerianus. The lowest beds of the overlying Tunnel Mountain formation generally contain green, possibly bentonitic, shales. This association of Gigantoproductus and green shales is very similar to that occuring at Lake Minnewanka, Highwood Pass and other sections south of Banff, where the productids occur in uppermost Mount Head (dated as late Meramecian), and the green shales in lowermost Etherington (dated as late Meramecian or early Chesterian - Nelson, personal communication).

The Gigantoproductus brazerianus beds at Tunnel Mountain occur about 1900 feet above the base of the Rundle and about 300 feet

below its top. At Banff, the Tunnel Mountain formation thus is separated from these productid beds by about 300 feet of carbonates. At Lake Minnewanka and northward to the Clearwater River however, the Tunnel Mountain rests directly upon these productid beds. Faunal evidence suggests that these relationships are best explained by the Tunnel Mountain lithofacies becoming older to the east and north of Banff, rather than by unconformable relationships. The occurrence of Spirifer leidyi Norwood and Pratten in basal Tunnel Mountain at Lake Minnewanka and to the north indicates a Chesterian age for the lower part of this formation. This age is also suggested by the green, possibly bentonitic, shales which occur in basal Tunnel Mountain at Lake Minnewanka and Mount White. As mentioned previously, similar shales occur in the basal Etherington formation from Highwood Pass to the International boundary and are dated as early Chesterian or late Meramecian (Nelson, personal communication).

North of Clearwater River, Gigantoproductus brazerianus is absent. At South Ram River however, the green shales, related to this fossil horizon, occur in the Middle Tunnel Mountain and suggest that the contact between the Upper member and Tunnel Mountain is older than that south of Clearwater River. Stratigraphic relationships suggest that the contact is equivalent in age to the Middle Mount Head (Mid-Meramecian).

North of South Ram River, the green shales are absent. The relatively constant thickness of the Upper member from here to Jasper

suggests that the Tunnel Mountain-Upper member contact remains approximately of the same age. Thus at Jasper, the contact is probably Mid-Meramecian so that an Upper Meramecian or early Chesterian age is suggested for the Tunnel Mountain there.

Tunnel Mountain Formation

The Tunnel Mountain formation over the present area correlates lithologically with type Tunnel Mountain and with the Middle and Upper members of Brown's (1952) Greenock formation.

As discussed on pp. 43&49, the lower boundary of the formation is thought to be diachronic. It is considered to be Pennsylvanian or late Chesterian at Banff, late Meramecian or early Chesterian from Lake Minnewanka north to the Clearwater River, and possibly Mid-Meramecian north to Jasper.

The almost complete lack of fossils in this formation over the present area makes age determination difficult. The few that have been found suggest that the lower part of the unit is Chesterian in age (See p. 52). The age of the upper part is not known. Pennsylvanian strata may be present in upper beds of thicker sections such as Lake Minnewanka (Shimer, 1926), Mount White and Peter's Creek. In most sections, the formation is relatively thin, probably due to erosion and is likely completely Mississippian in age.

PROBLEMS OF CORRELATION OF STRATA

Three main problems have arisen from this study. These are: correlation of the Shunda, correlation of the Pekisko, and correlation of the Tunnel Mountain.

The Shunda Problem

Of all the Mississippian rock units, the Shunda has been subjected to the most ambiguity. It apparently has been used for three widely-separated stratigraphic horizons: Mount Head, Middle Livingstone and Upper Banff. The first definition of the term (Beach, 1947) was apparently for strata equivalent to part of the Mount Head formation (See Fox, 1953, p. 197). This term never gained popular usage and is not valid because no description of the type section was given. The generally accepted usage of the term "Shunda" is for strata in the middle of the Livingstone between the Pekisko and Turner Valley members (Gallup, 1951, Raasch, 1958). Results of this thesis have shown that the third and correct usage of the term is for strata equivalent to Upper Banff and to type Shunda (Stearn, 1956). Moore (1958b) has tentatively suggested that this is the correct position for the Shunda.

Raasch (1958) has suggested that lateral equivalents of the southern subsurface Shunda are present in Middle Livingstone at Tunnel Mountain in the interval between 707 feet and 772 feet above

DESCRIPTION OF PLATE V

Figure 1: Tunnel Mountain section at Banff, Alberta showing the lower part (Livingstone formation) of type Rundle. According to Raasch (1958), the prominent black band is equivalent to the Shunda of Turner Valley.

Figure 2: Mount Rundle, showing the poorly-exposed Exshaw formation resting on Palliser. Weak exposures at the right are the basal siltstone beds of the Lower member of the Banff formation.

the base of the Rundle (See Plate 5, Figure 1, p. 55). As mentioned above, true Shunda is considerably lower stratigraphically.

The problem is: is the Shunda, as used in subsurface of the Turner Valley area and adjacent Rocky Mountains, the lateral equivalent of type Shunda or is it a higher horizon? Lack of detailed information, both palaeontologic and stratigraphic, on this southern area does not allow solution of the problem at present.

The Pekisko Problem

The Pekisko problem is intimately related to the Shunda problem and the term "Pekisko" has been applied to two distinct horizons. One is for beds immediately underlying type Shunda (Stearn, 1956), that is, Member C of this thesis; and the other for beds immediately overlying the Shunda equivalents, that is, basal type Rundle and its lateral continuants in the present area (Raasch, 1958).

Type Pekisko is geographically widely separated from type Shunda and has not, as yet, been formally described as to type section, lithology and fauna. Sparse descriptions of this formation (Douglas, 1953) suggests that the type section is in the Mount Head area. Thus, it is not known whether the Pekisko is the lateral continuation of Member C of this report or basal type Rundle and its lateral equivalents. If it should be later shown that Member C is equivalent to type Pekisko, then the term Livingstone, as applied by the present writer to the lower 1482 feet of type Rundle, is not

correct, so that perhaps, the name Turner Valley should be applied to this interval.

The Tunnel Mountain Problem

Raasch (1956) has stated that the clastics, lying above the Rundle of the present area (essentially the Tunnel Mountain formation of the writer) is Permian. His age determination was based upon fossils. The present writer's lithologic evidence, however, as well as S. J. Nelson's faunal evidence, suggest that this unit is actually in large part Mississippian (See p. 53). The age determination of these clastics require further work. It should be stated, in support of the present writer's conclusions, that nowhere has an unconformity been found between the Tunnel Mountain and Rundle. In fact, positive identification of the contact between these two units is often difficult because of their conformable relationship.

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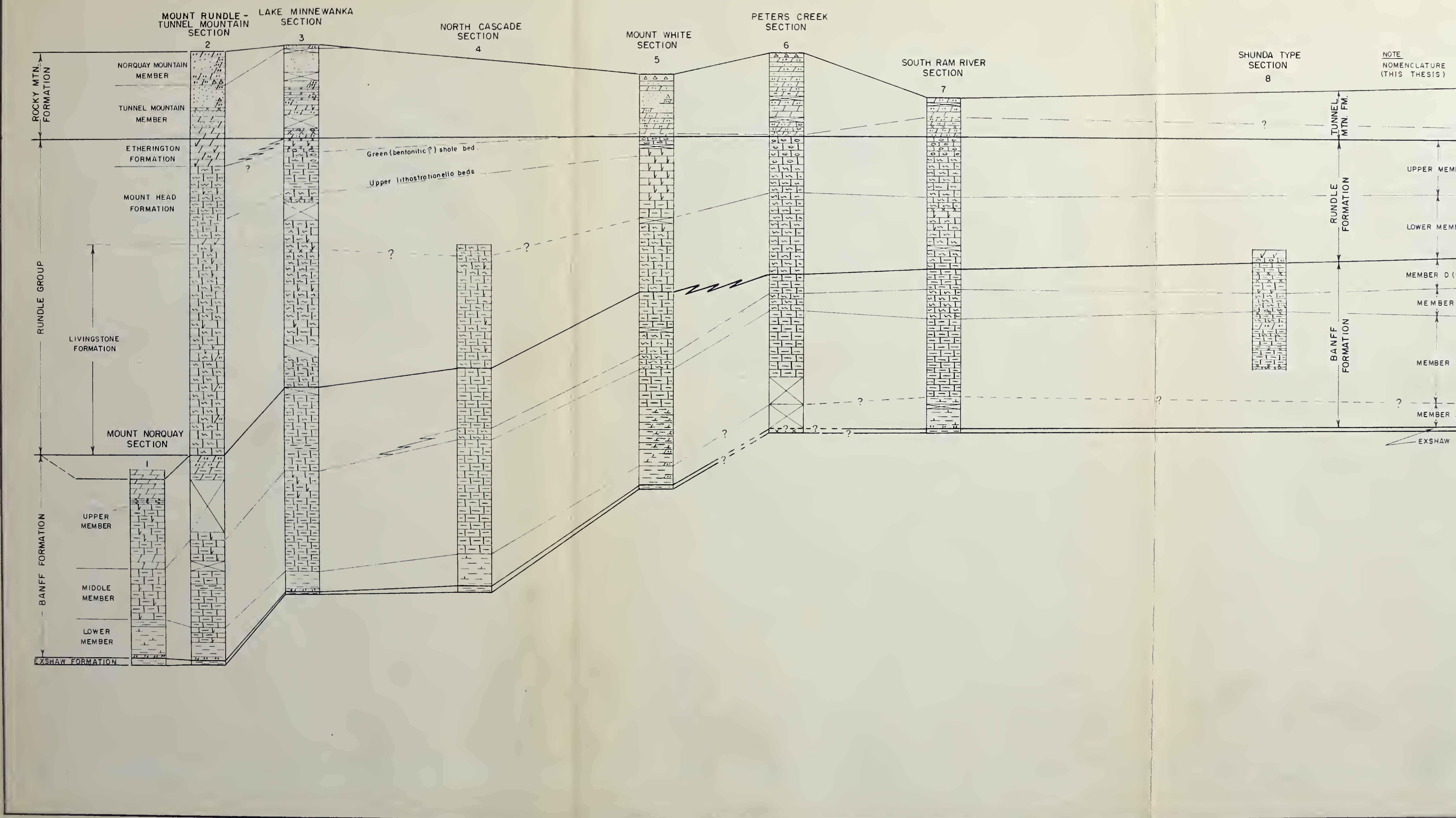
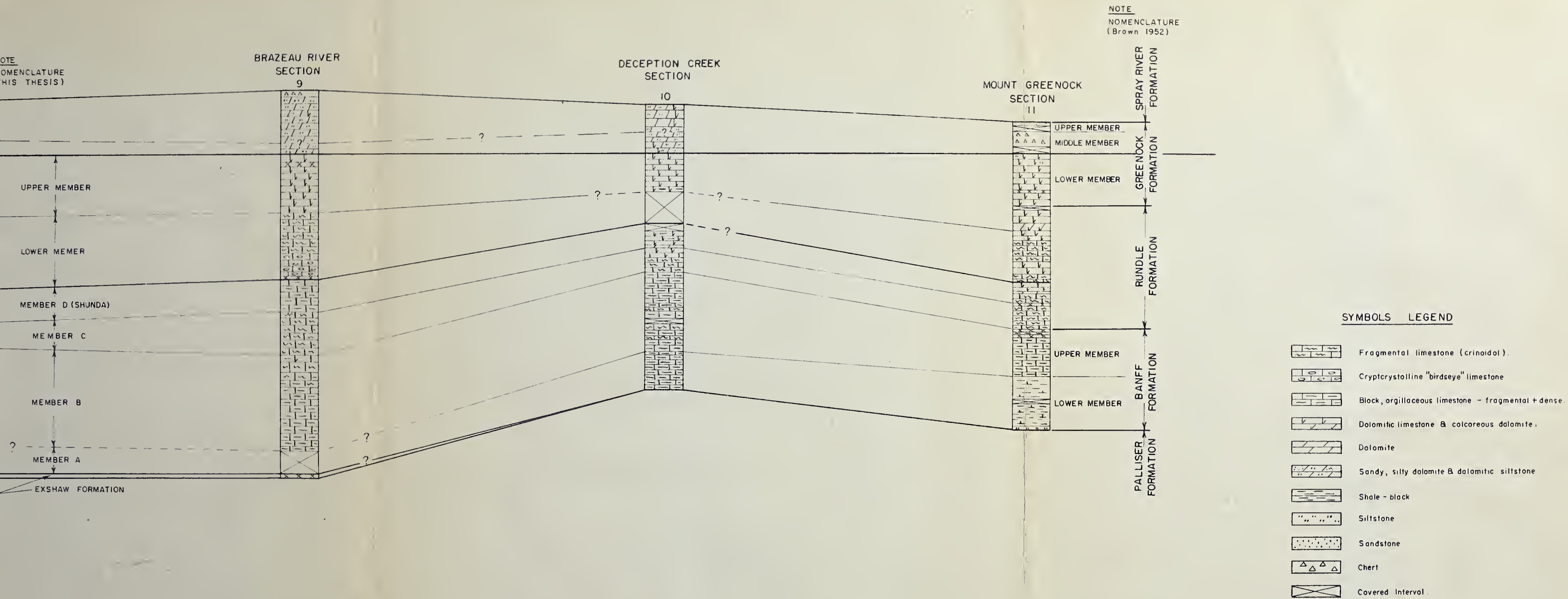


MOUNT RUNDLE - TUNNEL MOUNTAIN SECTION
2
LAKE MINNEWANKA SECTION
3
NORTH CASCADE SECTION
4
MOUNT WHITE SECTION
5
PETERS CREEK SECTION
6
SOUTH RAM RIVER SECTION
7
SHUNDA TYPE SECTION
8
NOTE
NOMENCLATURE (THIS THESIS)
MOUNT NORQUAY SECTION
1
ROCKY MTN. FORMATION
NORQUAY MOUNTAIN MEMBER
TUNNEL MOUNTAIN MEMBER
ETHERINGTON FORMATION
MOUNT HEAD FORMATION
RUNDLE GROUP
LIVINGSTONE FORMATION
BANFF FORMATION
UPPER MEMBER
MIDDLE MEMBER
LOWER MEMBER
EXSHAW FORMATION
Green (bentonitic?) shale bed
Upper lithostrotionella beds
TUNNEL MTN. FM.
RUNDLE FORMATION
BANFF FORMATION
UPPER MEM
LOWER MEM
MEMBER D
MEMBER
MEMBER
MEMBER
EXSHAW

TABLE 3



BANFF - JASPER AREA

STRATIGRAPHIC CORRELATION OF PERMO—CARBONIFEROUS OF ROCKY MOUNTAIN FRONT RANGES

VERTICAL SCALE 1 IN = 600 FT.

HORIZONTAL SCALE 1 IN = 10 MI.